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Methodology for Developing Best Demonstrated Available Technology (BDAT) Treatment Standards

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METHODOLOGY FOR DEVELOPING BEST DEMONSTRATED AVAILABLE TECHNOLOGY (BDAT) TREATMENT STANDARDS

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1. INTRODUCTION

The Hazardous and Solid Waste Amendments of 1984 (HSWA) imposed substantial new responsibilities on those who handle hazardous wastes, including stringent new restrictions on the land disposal of hazardous wastes and associated treatment residuals.

This document summarizes EPA's approach for implementing the land disposal restrictions program. Section 2 presents the legal authority under which the Agency is basing its regulations. Section 3 describes the technical methodology EPA uses to define treatment standards for restricted hazardous waste. Section 4 discusses variances from these treatment standards, and, finally, Section 5 presents the Agency's approach to the special problems raised by the P and U listed hazardous waste categories in 40 CFR /261.33.

2. LEGAL BACKGROUND

2.1 General Requirements Under HSWA

The Hazardous and Solid Waste Amendments of 1984 (HSWA), enacted on November 8, 1984, amended the Resource Conservation and Recovery Act of 1976 in several significant ways. Among other initiatives, the amendments require the Environmental Protection Agency (EPA) to promulgate regulations restricting the land disposal of hazardous wastes according to a strict and detailed schedule. This effort is generally referred to as the land disposal restrictions program.

In its enactment of HSWA, Congress stated explicitly that "...to avoid substantial risk to human health and the environment, reliance on land disposal should be minimized or eliminated, and land disposal, particularly landfill and surface impoundment, should be the least favored method for managing hazardous waste" (RCRA section 1002(b)(7), codified at 42 U.S.C. 6901(b)(7)). Exceptions to the restrictions are intended to be minimal: all wastes must be treated unless "it has been demonstrated to the Administrator, to a reasonable degree of certainty, that there will be no migration of hazardous constituents from the disposal unit or injection zone for as long as the wastes remain hazardous"--the so-called "no-migration" demonstration (RCRA section 3004(d)(1), (e)(1), (g)(5), codified at 42 U.S.C. 6924 (d)(1), (e)(1), (g)(5)).

Factors that must be taken into account when granting any exception to this program reflect the basic rationale of the program itself. Before it can allow a waste to continue to be disposed of in or on the land, EPA must consider (RCRA section 3004 (d)(1)(A-C):

1. The long-term uncertainties associated with land disposal,
2. The goal of managing hazardous waste in an appropriate manner in the first instance; and
3. The persistence, toxicity, mobility, and propensity to bioaccumulate such hazardous wastes and their hazardous constituents.

Consistent with the comprehensive scope of this program, HSWA's definition of land disposal is broad. Land disposal includes but is not limited to "any placement of hazardous waste in a landfill, surface impoundment, waste pile, injection well, land treatment facility, salt dome formation, salt bed formation, or underground mine or cave" (RCRA section 3004(k), codified at 42 U.S.C. 6924(k)). The statute does, however, set different schedules for restricting various categories of waste from various types of land disposal (see Section 2.2).

HSWA grants the Agency substantial flexibility in designing treatment standards to implement the program. The standards can require the use of specific "methods" (technologies), or they can be stated as numerical performance standards (i.e., required concentration-based levels of treatment), as long as they "substantially diminish the toxicity of the waste or substantially reduce the likelihood of migration of hazardous constituents from the waste so that short-term and long-term threats to human health and the environment are minimized" (RCRA section 3004(m)(1),

codified at 42 U.S.C. 6924 (m)(1)). In exercising this flexibility, E prefers, wherever possible, to establish numerical performance standards rather than to require the use of specific treatment methods. The Agency believes that concentration-based treatment standards offer the regulated community greater flexibility to develop and implement compliance strategies. Such standards also provide an incentive to develop innovative technologies.

EPA is not required to establish unique standards for each waste code. In some instances, variations in physical or chemical characteristics within a single waste code may require the establishment of multiple treatment standards for that single code. In other instances, similarities among wastes may allow the Agency to set a single treatment standard to cover multiple waste codes. Variances from standards are also possible in certain instances: if a generator can demonstrate that the standard promulgated for the generator's waste cannot be achieved, EPA can revise the treatment standard for that particular waste through rulemaking procedures.

2.2 Schedule for Developing Restrictions

HSWA set a strict and detailed schedule for establishing treatment standards, based generally on priorities related to the volume and intrinsic hazards of different types of wastes. Two groups received early attention: (1) solvent and dioxin wastes, to be regulated within 24 months of HSWA's passage and (2) the so-called "California List" wastes, to be regulated within 32 months. The solvent/dioxin waste group

identified in HSWA includes those solvent wastes covered under waste codes F001, F002, F003, F004, and F005, as well as the dioxin-containing wastes covered under waste codes F020, F021, F022, and F023 (RCRA 3004(e))*.

The California List wastes, a group of wastes originally listed by the State of California and adopted intact within HSWA, include liquid hazardous wastes containing metals, free cyanides, PCBs, corrosives (pH less than or equal to 2.0), and any liquid or nonliquid hazardous waste containing halogenated organic compounds (HOCs) above 0.1 percent by weight.

Priorities for all other hazardous waste listed under RCRA section 3001 were established separately, based on considerations of volume and intrinsic hazard, in a formal schedule submitted to Congress on November 8, 1986 (RCRA section 3004(g)(1)). This schedule requires all land disposal restriction regulations to be in place by May 8, 1990. Consistent with the requirements of HSWA, EPA divided all other listed hazardous wastes into three groups (the "Thirds"), to be regulated in successive stages over a period of 66 months from the passage of HSWA on November 8, 1984.

The overall schedule for the land disposal restrictions program is as follows:

- Solvents and dioxins: Final standards promulgated on November 7, 1986.

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* The final dioxin regulation also established treatment standards for F026, F027, and F028.

- California List wastes: Final standards promulgated on July 8, 1987.
- "First Third" scheduled wastes: Final standards promulgated on August 8, 1988.
- "Second Third" scheduled wastes: Final standards to be promulgated on or before June 8, 1989.
- "Third Third" scheduled wastes: Final standards to be promulgated on or before May 8, 1990.

2.3 Variances from the Schedule

The land disposal restrictions are effective when promulgated unless the Administrator grants a national variance and establishes a different date, not to exceed 2 years beyond the statutory deadline, based on "the earliest date on which adequate alternative treatment, recovery, or disposal capacity which protects human health and the environment will be available" (RCRA section 3004(h)(2), codified at 42 U.S.C. 6924 (h)(2)).

In addition, if EPA fails to set a treatment standard by the statutory deadline for any hazardous waste in the First Third or Second Third of the scheduled wastes, the waste may continue to be disposed of in a landfill or surface impoundment, but only if the facility is in compliance with the minimum technological requirements specified in RCRA section 3004 (o). Furthermore, prior to such disposal, generators must certify to EPA that (1) they have investigated available treatment capacity, (2) they have determined that disposal in a landfill or surface impoundment is the only practical alternative to treatment currently available to the generator, and (3) the waste, if currently treated, is being treated to the fullest extent feasible in the existing treatment

system. Such continued land disposal is allowed until EPA sets a standard for the waste in question, or until May 8, 1990, whichever is sooner. If the Agency has not set a standard by May 8, 1990, the waste is automatically prohibited from further land disposal.

After May 8, 1990, the only general variance allowed from the land disposal restrictions standards will be if wastes are disposed of in a land disposal unit that has made a successful "no migration" demonstration. These demonstrations are based on case-by-case petitions that must show that there will be no migration of hazardous constituents from the disposal unit for as long as the waste remains hazardous.

3. METHODOLOGY FOR ESTABLISHING TREATMENT STANDARDS

RCRA section 3004(m) specifies that treatment standards must minimize long- and short-term threats to human health and the environment arising from land disposal of hazardous wastes. EPA's general approach for complying with this requirement was promulgated as part of the November 7, 1986, rule. It is summarized here.

The legislative history accompanying HSWA states that technical methods used for treating hazardous waste should be "the best that has been demonstrated to be achievable," but it notes that Congress's intent is "to require utilization of available technology" and not a "process which contemplates technology-forcing standards" (Vol. 130 Cong. Rec. S9178 (daily edition, July 25, 1984)). The word "achievable," therefore, does not require the use of experimental or emerging technologies in developing treatment standards. Rather, the intent of the statute is to base treatment standards on the best technologies commonly in use and thus reasonably available to any generator.

Accordingly, EPA's treatment standards, usually stated in terms of concentrations of hazardous constituents in treatment residues (such as sludges, ashes, or wastewaters), are generally based on the performance of the "best demonstrated available technology," or BDAT. This approach involves the identification of applicable treatment systems for individual wastes or for groups of wastes, determination of whether these systems are "demonstrated" and "available," selection of the "best" of

those that are demonstrated and available, and collection of treatment data from representative well-designed and well-operated systems to serve as the basis for numerical performance standards.

The approach ensures that concentration-based performance standards are achievable in practice using available technology, but it does not specifically mandate the use of any particular technology in order to comply with the standard. Treaters are free to use any method they choose, as long as the results are equal to, or better than, use of the model BDAT technology.

In cases where analytical methods are not available to measure and assure compliance for the constituents of concern, a method of treatment is established as the BDAT treatment standard. Treaters are required to use the established technology to treat the waste For these cases, concentration-based standards may be established in the future should an analytical method be developed to measure the constituents of concern or should an adequate surrogate or indicated constituent be identified to measure treatment and assure compliance.

3.1 Waste Treatability Groups

To set standards efficiently, wastes are clustered into "treatability groups" that are similar with respect to various parameters that might affect the success of treatment. These parameters can include such factors as physical state, water content, presence of similar hazardous and nonhazardous contaminants, organic content, heat content, pH, and so forth. As noted, waste treatability groups can include multiple waste

codes, single waste codes, or subcategories of a single waste code, in any combination.

The process of establishing and refining treatability groups is a continuous one within the standard-setting process. Tentative groupings, such as those presented for the P and U wastes in Section 5 of this report, may therefore change before promulgation of the final standards. The general concept of a treatability group, however, is helpful to identification of BDAT for any given waste code or any subcategories of a waste code.

3.2 Determining BDAT for Individual Waste Treatability Groups

For any particular waste treatability group, EPA first identifies applicable technologies either through literature reviews or on the basis of information provided by facilities currently treating the waste or similar wastes. In some instances, technologies used to separate or process chemicals or other materials are frequently applicable to waste treatment and may therefore form the basis of a standard, because certain wastes are similar to raw materials processed in various industrial applications.

From among the applicable technologies, EPA then identifies those that are "demonstrated" for the particular treatability group. To be considered demonstrated, a technology must be used in a full-scale operation for treatment of the waste or a similar waste. Where the Agency does not identify any facilities treating specific wastes from a particular group, it may "transfer" a finding of demonstrated treatment

by comparing the parameters that affect treatment of the target waste group to parameters of other waste groups for which demonstrated treatments are known. For example, on the basis of technical literature and data collected by the Agency, EPA considers rotary kiln incineration to be a demonstrated technology for many waste codes containing hazardous organic constituents, high total organic content, and high filterable solids content, regardless of whether any facility is currently treating these wastes using incineration.

The next step is to determine which of the demonstrated technologies is "best" for the purposes of establishing BDAT. In defining "best," EPA considers only the effectiveness of treatment--the degree to which hazardous constituents in the waste are removed or destroyed. Economic factors are not considered under RCRA.

If only one technology is demonstrated for a particular waste group, then that technology is automatically "best." If two or more technologies are available, but acceptable data exist for only one of them, then the Agency must make a judgment as to whether to develop new data or to use engineering judgment to determine if the performance of the documented technology is likely to be equal to, or better than, the others. If several technologies are available, each with acceptable performance data, then the Agency compares the performance of these technologies using their available data.

Any such comparisons must be statistically defensible to the extent that sample sizes and other technical factors permit. First, prior to

performing statistical tests, the Agency must adjust the measured results to account for the accuracy of the laboratory procedure used to generate the data (see the detailed discussion in Section 3.3). Second, where possible it may compare the adjusted performance levels using the statistical "analysis of variance" (ANOVA) technique to ensure that the technology selected as "best" does indeed perform statistically better than the others (see Appendix A-2, "F Value Determination for ANOVA Test"). If the differences among the available data sets are not statistically significant, then two or more technologies can be considered as being "best demonstrated."

Next, the Agency determines whether the best demonstrated technology or technologies is "available." "Available" technologies must be both commercially available and provide "substantial treatment." To be considered commercially available, the technology may be either a common technology in universal use (such as neutralization or incineration), or a proprietary or patented process that can be purchased or licensed from the proprietor or that is commercially available at a facility offering use of the technology for a fee.

To be considered as providing "substantial treatment," a technology must, consistent with the language of HSWA, "substantially diminish the toxicity" of a waste or "substantially reduce the likelihood of migration of hazardous constituents" from the waste (section 3004(m)). By establishing that treatment is "substantial," the Agency both ensures compliance with statutory objectives and avoids requiring a treatment method that provides little or no environmental benefit.

Treatment will always be considered substantial if the residuals from treatment contain nondetectable levels of the hazardous constituents of concern. If concentrations are detectable, then a finding of substantial treatment must be made on a case-by-case basis, considering the following:

- Number and types of constituents treated,
- Performance (concentration of the constituents in the treatment residuals), and
- Percent of constituents removed.

EPA has used both total constituent concentration and TCLP analyses of the treated waste as a measure of technology performance and for later establishment of treatment standards. For organic constituents, EPA measures performance based on the total constituent concentration found in the treated waste. This is because technologies exist to destroy various organic compounds in waste, making the total amount of constituent left in the treated waste the more logical measure of performance.* For all metal constituents, EPA is using total constituent and/or the TCLP as the basis for evaluating performance. When BDAT involves a metals recovery operation, EPA uses both total concentrations and TCLP to measure performance, because it is important to establish both the effectiveness of recovery (measure by changes in total concentration) and the stability of any treated residuals that may

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* EPA's land disposal restrictions for solvent waste codes F001-F005 (51 FR 40572) use the TCLP value as a measure of performance. At the time that EPA promulgated the treatment standards for these wastes, useful data were not available on total constituent concentrations in treated residuals and, as a result, the TCLP data were considered to be the best measure of performance.

be sent to land disposal (TCLP test of the residuals). When BDAT for metals involves only treatment as opposed to recovery, that treatment is generally stabilization, so the appropriate measure of performance of stabilization is the TCLP test.

If, for any reason, a demonstrated or available technology cannot be defined for a particular waste treatability group, EPA cannot establish a treatment standard for that waste group. Wastes in the group would then be prohibited from continued land disposal, unless managed in accordance with the exemptions and variances discussed above (especially the no-migration standard). EPA is committed, however, to establishing treatment standards as soon as new or improved treatment processes become demonstrated and available.

3.3 Establishing Numerical Performance Standards on the Basis of BDAT

Once BDAT is determined for a particular treatability group, EPA prefers, wherever possible, to define numerical performance standards in terms of concentrations of hazardous constituents in the treated waste and in any nonwastewater and wastewater residuals that might be produced. For example, for wastes for which BDAT is incineration, the Agency may have to define maximum allowable concentrations of hazardous constituents in associated bottom ash, scrubber water, and possibly sludges resulting from treatment of scrubber water.

EPA develops treatment standards using performance data gathered from representative facilities. Only data from well-designed and well-operated facilities are accepted as usable--a judgment made on a

case-by-case basis for each set of potentially usable data. Data neec not be generated only by EPA; the Agency may use data submitted by industry, provided these data are shown to be from a well-designed and well-operated facility and were generated using adequate quality control and quality assurance procedures for laboratory data. (EPA's policies and procedures for collecting new performance data, where needed, are discussed in Section 3.4.)

3.3.1 Evaluating the Adequacy of Existing Data

All valid data available to the Agency may be used to establish BDAT-based performance standards. They may be generated by EPA or its contractors, by research organizations or universities, or by industry. Whatever the source, however, all the data underlying all performance standards must meet explicit standards of quality assurance and quality control. If the available data for a given technology/waste group combination are <u>not</u> of adequate quality, then data can be "transferred" from another standard if they meet certain conditions. These issues are discussed separately below.

(1) Criteria for accepting existing data. EPA considers a number of factors in evaluating data sets as the possible basis for BDAT standards.

1. All data must come from technologies that are demonstrated and available.

2. The facility from which the data were generated must be well-designed and well-operated. Adequacy of design can generally be determined through review of facility specifications; the essential requirement is that the facility include all processes needed to handle the hazardous constituents in the target waste group, as well as all

nonhazardous constituents that could affect the system's performance in treating the hazardous constituents. Adequacy of operation must be determined based on a review of the performance range operating parameters used during the sampled test versus the operating specifications.

3. EPA reviews the adequacy of the quality assurance and quality control protocols followed in generating the laboratory analytical data. If these protocols are substandard or nonexistent, the data are discarded.

4. All candidate data sets must use measures of performance consistent with those being used to set the standard (e.g., total constituent analysis for all hazardous (organic and inorganic) parameters and TCLP analysis for metals in the treated residuals, if appropriate).

5. For a data set to be accepted in whole or in part, the data must show substantial treatment on a constituent-by-constituent basis. Data must be provided for both untreated and treated concentrations. Treated concentrations must be lower than untreated concentrations. Often common sense will suffice to determine whether the degree of treatment provided is significant, but, if necessary, statistical tests can be used to arrive at a formal finding of substantial treatment.

6. Data on concentrations in treated waste must be adjusted for accuracy using recovery factors specific to the laboratory tests used (see Appendix A-1).

In situations where the available data show substantial treatment for one class of constituents but not for another, the Agency may conclude that the standard should be based on a treatment "train" of multiple BDAT technologies operating as a system. This might be the case, for instance, in treating wastes that include both organics and metals. Incineration might show substantial treatment of the organics, but not of the metals, which might require another form of treatment, such as stabilization.

(2) Transfer of treatment data or standards. In some instances, EPA is proposing treatment standards that are not based on tests of the waste

in question by the selected BDAT technology. It may do this when it determines that the constituents present in the subject waste can be treated to the same performance levels as those observed in other wastes for which EPA has previously developed treatment data. EPA believes such transfers may be technically valid in cases where the untested wastes are generated from similar industries or from similar processing steps, or have similar waste characteristics affecting performance and treatment selection.

Transfer of treatment standards to similar wastes or to wastes from similar processing steps requires a detailed comparison of the constituents of concern in the untested waste to those in the tested waste. If the parameters that affect treatment performance for these constituents indicate that the untreated waste is equal to, or easier to treat than the tested waste, then the transfer can be made.

3.3.2 Collecting Additional Performance Data

If adequate data are not available for use in setting a performance standard, the Agency collects additional data through a standardized sampling and analysis procedures at existing facilities that generate or treat the wastes of concern.

(1) Identification of facilities. EPA uses a number of sources to identify candidate sources for sampling and analysis. These include Stanford Research Institute's Directory of Chemical Producers; EPA's Hazardous Waste Data Management Systems (HWDMS); the 1986 Treatment, Storage, and Disposal Facility (TSDF) National Screening Survey; and

EPA's Industry Studies Data Base. EPA also contacts trade associations to solicit help in identifying appropriate facilities.

To the extent possible, EPA prefers to develop data from a generator/treator or a commercial treatment facility handling only a single waste, believing that facilities that routinely treat a specific waste have had the best opportunity to optimize design and operating parameters. It also prefers to avoid ambiguities created by the mixing of wastes before and during treatment. If several facilities appear to be equally desirable for sampling, EPA selects sites strictly on the basis of which facilities can be most expeditiously visited and, if justified, sampled.

Wherever possible, the Agency will evaluate treatment technologies using commercially operated systems. If performance data from properly designed and operated commercial treatment methods for a particular waste, or a waste judged to be similar, are not available, EPA may use data from research facilities. Whenever research facility data are used, EPA will explain in the preamble and background document for the rule in question why such data were used, and will request comments on the use of such data.

(2) Engineering site visit. Once a facility is selected, EPA visits the site to confirm that it is well-designed and that the necessary sampling points are accessible. In general, EPA considers a well-designed facility to be one that contains the unit operations or unit processes necessary to treat the various hazardous constituents of

the selected waste, as well as to control other nonhazardous materials in the waste that may affect treatment performance. During the visit, the Agency also confirms that the facility appears to be well-operated; actual operation of the treatment system during sampling, however, is the basis for determining the proper operation of the treatment unit.

(3) Sampling and analysis plan. If, after the engineering site visit, EPA decides to sample a particular facility, it will then develop a site-specific Sampling and Analysis Plan (SAP) following the Generic Quality Assurance Project Plan for the Land Disposal Restriction Program ("BDAT") (EPA/5030-SW-87-011). The SAP is based on sampling procedures discussed with plant personnel during the site visit. It describes where the sampling will take place, how the samples will be taken, the frequency of sampling, the constituents to be analyzed and the methods of analysis, the operation parameters to be obtained, and specific laboratory quality control checks on analytical results. The SAP is sent to the plant for review and comment.

Facilities wishing to submit data independently for consideration in the development of BDAT standards should, to the extent possible, follow the procedures described in EPA/5030-SW-87-011.

(4) Sampling visit. While actually sampling a particular facility, EPA attempts to collect sufficient samples of the untreated waste and any solid or liquid residuals so that the inherent variability of the process can be properly reflected in the final performance standard. It also documents the operating conditions that existed during the waste

treatment period. To the extent practicable (and within safety constraints), EPA or its contractors collect the samples themselves and follow chain-of-custody procedures to ensure that the integrity of tne data is maintained. Any deviations from the SAP, such as those that might be necessary because of plant upsets or changes in facility operation, are noted.

(5) Onsite Engineering Report. EPA summarizes all its data collection activities, associated analytical results, and any deviations from planned procedures in a formal Onsite Engineering Report. After review by the plant, the report, except for material claimed by the plant as confidential, is made available to the public.

3.3.3 Hazardous Constituents Considered for Regulation

The list of hazardous constituents for which BDAT performance standards may be established is known as the BDAT Constituent List. This list, provided as currently amended in Table 3-1, is a subset of the constituents listed in 40 CFR Part 261, Appendix VIII; it also includes several ignitable constituents used as the basis for listing wastes as F003 and F005. Chemicals are listed in Appendix VIII if they are shown in scientific studies to have toxic, carcinogenic, mutagenic, or teratogenic effects on humans or other life forms; for instance, they include such substances as those identified by the Agency's Carcinogen Assessment Group as being carcinogenic.

There are five major reasons why not all Appendix VII and VIII constituents or the F003 and F005 ignitables are included on the BDAT Constituent List:

Table 3-1 BDAT Constituent List

BDAT reference no.	Constituent	CAS no.
	Volatile organics	
222.	Acetone	67-64-1
1.	Acetonitrile	75-05-8
2.	Acrolein	107-02-8
3.	Acrylonitrile	107-13-1
4.	Benzene	71-43-2
5.	Bromodichloromethane	75-27-4
6.	Bromomethane	74-83-9
223.	n-Butyl alcohol	71-36-3
7.	Carbon tetrachloride	56-23-5
8.	Carbon disulfide	75-15-0
9.	Chlorobenzene	108-90-7
10.	2-Chloro-1,3-butadiene	126-99-8
11.	Chlorodibromomethane	124-48-1
12.	Chloroethane	75-00-3
13.	2-Chloroethyl vinyl ether	110-75-8
14.	Chloroform	67-66-3
15.	Chloromethane	74-87-3
16.	3-Chloropropene	107-05-1
17.	1,2-Dibromo-3-chloropropane	96-12-8
18.	1,2-Dibromoethane	106-93-4
19.	Dibromomethane	74-95-3
20.	trans-1,4-Dichloro-2-butene	110-57-6
21.	Dichlorodifluoromethane	75-71-8
22.	1,1-Dichloroethane	75-34-3
23.	1,2-Dichloroethane	107-06-2
24.	1,1-Dichloroethylene	75-35-4
25.	trans-1,2-Dichloroethene	156-60-5
26.	1,2-Dichloropropane	78-87-5
27.	trans-1,3-Dichloropropene	10061-02-6
28.	cis-1,3-Dichloropropene	10061-01-5
29.	1,4-Dioxane	123-91-1
224.	2-Ethoxyethanol	110-80-5
225.	Ethyl acetate	141-78-6
226.	Ethyl benzene	100-41-4
30.	Ethyl cyanide	107-12-0
227.	Ethyl ether	60-29-7
31.	Ethyl methacrylate	97-63-2
214.	Ethylene oxide	75-21-8
32.	Iodomethane	74-88-4
33.	Isobutyl alcohol	78-83-1
228.	Methanol	67-56-1
34.	Methyl ethyl ketone	78-93-3

Table 3-1 (Continued)

BDAT reference no.	Constituent	CAS no.
	Volatile organics (continued)	
229.	Methyl isobutyl ketone	108-10-1
35.	Methyl methacrylate	80-62-6
37.	Methacrylonitrile	126-98-7
38.	Methylene chloride	75-09-2
230.	2-Nitropropane	79-46-9
39.	Pyridine	110-86-1
40.	1,1,1,2-Tetrachloroethane	630-20-6
41.	1,1,2,2-Tetrachloroethane	79-34-6
42.	Tetrachloroethene	127-18-4
43.	Toluene	108-88-3
44.	Tribromomethane	75-25-2
45.	1,1,1-Trichloroethane	71-55-6
46.	1,1,2-Trichloroethane	79-00-5
47.	Trichloroethene	79-01-6
48.	Trichloromonofluoromethane	75-69-4
49.	1,2,3-Trichloropropane	96-18-4
231.	1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1
50.	Vinyl chloride	75-01-4
215.	1,2-Xylene	97-47-6
216.	1,3-Xylene	108-38-3
217.	1,4-Xylene	106-44-5
	Semivolatile organics	
51.	Acenaphthalene	208-96-8
52.	Acenaphthene	83-32-9
53.	Acetophenone	96-86-2
54.	2-Acetylaminofluorene	53-96-3
55.	4-Aminobiphenyl	92-67-1
56.	Aniline	62-53-3
57.	Anthracene	120-12-7
58.	Aramite	140-57-8
59.	Benz(a)anthracene	56-55-3
218.	Benzal chloride	98-87-3
60.	Benzenethiol	108-98-5
61.	Deleted	
62.	Benzo(a)pyrene	50-32-8
63.	Benzo(b)fluoranthene	205-99-2
64.	Benzo(ghi)perylene	191-24-2
65.	Benzo(k)fluoranthene	207-08-9
66.	p-Benzoquinone	106-51-4

Table 3-1 (Continued)

BDAT reference no.	Constituent	CAS no.
	Semivolatile organics (continued)	
67.	Bis(2-chloroethoxy)methane	111-91-1
68.	Bis(2-chloroethyl)ether	111-44-4
69.	Bis(2-chloroisopropyl)ether	39638-32-9
70.	Bis(2-ethylhexyl)phthalate	117-81-7
71.	4-Bromophenyl phenyl ether	101-55-3
72.	Butyl benzyl phthalate	85-68-7
73.	2-sec-Butyl-4,6-dinitrophenol	88-85-7
74.	p-Chloroaniline	106-47-8
75.	Chlorobenzilate	510-15-6
76.	p-Chloro-m-cresol	59-50-7
77.	2-Chloronaphthalene	91-58-7
78.	2-Chlorophenol	95-57-8
79.	3-Chloropropionitrile	542-76-7
80.	Chrysene	218-01-9
81.	ortho-Cresol	95-48-7
82.	para-Cresol	106-44-5
232.	Cyclohexanone	108-94-1
83.	Dibenz(a,h)anthracene	53-70-3
84.	Dibenzo(a,e)pyrene	192-65-4
85.	Dibenzo(a,i)pyrene	189-55-9
86.	m-Dichlorobenzene	541-73-1
87.	o-Dichlorobenzene	95-50-1
88.	p-Dichlorobenzene	106-46-7
89.	3,3'-Dichlorobenzidine	91-94-1
90.	2,4-Dichlorophenol	120-83-2
91.	2,6-Dichlorophenol	87-65-0
92.	Diethyl phthalate	84-66-2
93.	3,3'-Dimethoxybenzidine	119-90-4
94.	p-Dimethylaminoazobenzene	60-11-7
95.	3,3'-Dimethylbenzidine	119-93-7
96.	2,4-Dimethylphenol	105-67-9
97.	Dimethyl phthalate	131-11-3
98.	Di-n-butyl phthalate	84-74-2
99.	1,4-Dinitrobenzene	100-25-4
100.	4,6-Dinitro-o-cresol	534-52-1
101.	2,4-Dinitrophenol	51-28-5
102.	2,4-Dinitrotoluene	121-14-2
103.	2,6-Dinitrotoluene	606-20-2
104.	Di-n-octyl phthalate	117-84-0
105.	Di-n-propylnitrosamine	621-64-7
106.	Diphenylamine	122-39-4
219.	Diphenylnitrosamine	86-30-6

Table 3-1 (Continued)

BDAT reference no.	Constituent	CAS no.
	Semivolatile organics (continued)	
107.	1,2-Diphenylhydrazine	122-66-7
108.	Fluoranthene	206-44-0
109.	Fluorene	86-73-7
110.	Hexachlorobenzene	118-74-1
111.	Hexachlorobutadiene	87-68-3
112.	Hexachlorocyclopentadiene	77-47-4
113.	Hexachloroethane	67-72-1
114.	Hexachlorophene	70-30-4
115.	Hexachloropropene	1888-71-7
116.	Indeno(1,2,3-cd)pyrene	193-39-5
117.	Isosafrole	120-58-1
118.	Methapyrilene	91-80-5
119.	3-Methylcholanthrene	56-49-5
120.	4,4'-Methylenebis (2-chloroaniline)	101-14-4
36.	Methyl methanesulfonate	66-27-3
121.	Naphthalene	91-20-3
122.	1,4-Naphthoquinone	130-15-4
123.	1-Naphthylamine	134-32-7
124.	2-Naphthylamine	91-59-8
125.	p-Nitroaniline	100-01-6
126.	Nitrobenzene	98-95-3
127.	4-Nitrophenol	100-02-7
128.	N-Nitrosodi-n-butylamine	924-16-3
129.	N-Nitrosodiethylamine	55-18-5
130.	N-Nitrosodimethylamine	62-75-9
131.	N-Nitrosomethylethylamine	10595-95-6
132.	N-Nitrosomorpholine	59-89-2
133.	N-Nitrosopiperidine	100-75-4
134.	N-Nitrosopyrrolidine	930-55-2
135.	5-Nitro-o-toluidine	99-65-8
136.	Pentachlorobenzene	608-93-5
137.	Pentachloroethane	76-01-7
138.	Pentachloronitrobenzene	82-68-8
139.	Pentachlorophenol	87-86-5
140.	Phenacetin	62-44-2
141.	Phenanthrene	85-01-8
142.	Phenol	108-95-2
220.	Phthalic anhydride	85-44-9
143.	2-Picoline	109-06-8
144.	Pronamide	23950-58-5
145.	Pyrene	129-00-0
146.	Resorcinol	108-46-3

Table 3-1 (Continued)

BDAT reference no.	Constituent	CAS no.
	Semivolatile organics (continued)	
147.	Safrole	94-59-7
148.	1,2,4,5-Tetrachlorobenzene	95-94-3
149.	2,3,4,6-Tetrachlorophenol	58-90-2
150.	1,2,4-Trichlorobenzene	120-82-1
151.	2,4,5-Trichlorophenol	95-95-4
152.	2,4,6-Trichlorophenol	88-06-2
153.	Tris(2,3-dibromopropyl) phosphate	126-72-7
	Metals	
154.	Antimony	7440-36-0
155.	Arsenic	7440-38-2
156.	Barium	7440-39-3
157.	Beryllium	7440-41-7
158.	Cadmium	7440-43-9
159.	Chromium (total)	7440-47-3
221.	Chromium (hexavalent)	-
160.	Copper	7440-50-8
161.	Lead	7439-92-1
162.	Mercury	7439-97-6
163.	Nickel	7440-02-0
164.	Selenium	7782-49-2
165.	Silver	7440-22-4
166.	Thallium	7440-28-0
167.	Vanadium	7440-62-2
168.	Zinc	7440-66-6
	Inorganics other than metals	
169.	Cyanide	57-12-5
170.	Fluoride	16964-48-8
171.	Sulfide	8496-25-8
	Organochlorine pesticides	
172.	Aldrin	309-00-2
173.	alpha-BHC	319-84-6
174.	beta-BHC	319-85-7
175.	delta-BHC	319-86-8

Table 3-1 (Continued)

BDAT reference no.	Constituent	CAS no.
	Organochlorine pesticides (continued)	
176.	gamma-BHC	58-89-9
177.	Chlordane	57-74-9
178.	DDD	72-54-8
179.	DDE	72-55-9
180.	DDT	50-29-3
181.	Dieldrin	60-57-1
182.	Endosulfan I	939-98-8
183.	Endosulfan II	33213-6-5
184.	Endrin	72-20-8
185.	Endrin aldehyde	7421-93-4
186.	Heptachlor	76-44-8
187.	Heptachlor epoxide	1024-57-3
188.	Isodrin	465-73-6
189.	Kepone	143-50-0
190.	Methoxyclor	72-43-5
191.	Toxaphene	8001-35-2
	Phenoxyacetic acid herbicides	
192.	2,4-Dichlorophenoxyacetic acid	94-75-7
193.	Silvex	93-72-1
194.	2,4,5-T	93-76-5
	Organophosphorous insecticides	
195.	Disulfoton	298-04-4
196.	Famphur	52-85-7
197.	Methyl parathion	298-00-0
198.	Parathion	56-38-2
199.	Phorate	298-02-2
	PCBs	
200.	Aroclor 1016	12674-11-2
201.	Aroclor 1221	11104-28-2
202.	Aroclor 1232	11141-16-5
203.	Aroclor 1242	53469-21-9
204.	Aroclor 1248	12672-29-6
205.	Aroclor 1254	11097-69-1
206.	Aroclor 1260	11096-82-5

Table 3-1 (Continued)

BDAT reference no.	Constituent	CAS no.
	Dioxins and furans	
207.	Hexachlorodibenzo-p-dioxins	-
208.	Hexachlorodibenzofurans	-
209.	Pentachlorodibenzo-p-dioxins	-
210.	Pentachlorodibenzofurans	-
211.	Tetrachlorodibenzo-p-dioxins	-
212.	Tetrachlorodibenzofurans	-
213.	2,3,7,8-Tetrachlorodibenzo-p-dioxin	1746-01-6

1. A constituent may be unstable. Based on their chemical structure, some constituents will either decompose in water or will ionize. For example, maleic anhydride will form maleic acid when it comes in contact with water, and copper cyanide will ionize to form copper and cyanide atoms. EPA may, however, choose to regulate the decomposition and ionization products.

2. EPA-approved or verified analytical methods are not available. Many constituents, such as 1,3,5-trinitronobenzene, are not measured adequately, or even detected, using EPA's analytical methods as published in SW-846 Third Edition.

3. The constituent is a member of a chemical group designated in Appendix VIII as "not otherwise specified" (N.O.S.). Constituents listed as N.O.S., such as chlorinated phenols, are a generic group of some types of chemicals for which a single analytical procedure is not available. For each N.O.S. group, constituents that can be readily analyzed are included in the BDAT Constituent List.

4. Available analytical procedures are not appropriate for a complex waste matrix. Some compounds, such as auramine, can be analyzed as a pure constituent, but the recommended analytical method may not positively identify it in the presence of other constituents, or in a complex waste matrix.

5. Standards for analytical instrument calibration are not commercially available. For several constituents, such as benz(c)acridine, commercially available standards of an adequately pure grade are not available.

The BDAT Constituent List is a continuously growing list that does not preclude the addition of new constituents as the problems above are resolved. The initial list was published in EPA's Generic Quality Assurance Plan (EPA/530-SW-87-011); since then, 18 additional constituents have been added. Two constituents (fluoride and sulfide) are not specifically included in Appendix VIII, but are included in the BDAT list as indicators for certain Appendix VIII constituents, such as hydrogen fluoride and hydrogen sulfide, which ionize in water.

3.3.4 Selecting Constituents for Inclusion in the Standard

A performance standard for treating a particular waste group will list acceptable concentrations of BDAT list constituents in treated residuals. The standard will not necessarily include all BDAT list constituents analyzed in a particular waste stream, and may, in some instances, include one or more BDAT list constituents that have not been detected in the waste stream. The rationale for selecting constituents for inclusion in a standard is as follows.

The constituents considered for regulation in each treatability group are, in general, those for which available data show statistically significant reductions in concentrations resulting from treatment. This process involves the use of the statistical analysis of variance (ANOVA) test described in Appendix A-2. EPA interprets a statistically significant reduction in concentration as evidence that the technology actually "treats" the waste.

There are some instances where EPA may regulate constituents that are <u>not</u> detected in the untreated waste but which are detected in the analyzed residual (ash, sludge, etc.). This may happen, for instance, where the presence of other constituents in the untreated waste matrix interferes with quantification of the constituent of concern. The result may be a finding of "not detected," when in fact the constituent is present in the waste. EPA may also choose to consider a constituent not found in a sampled untreated waste if it believes that the constituent is likely to be present in the same hazardous waste generated by another source. For example, EPA may choose to regulate all conceivable

hazardous solvents that might be used in paint or ink manufacture, even if its sample data do not include them all.

EPA then reviews the list of candidate constituents to determine whether any can be excluded from regulation because they would be indirectly controlled by regulation of other constituents. For instance, an incineration regulation might choose to regulate only the least combustible organic compounds present in the waste, since achievement of a standard for these compounds would assure achievement of adequate treatment for the others. This approach (1) reduces analytical cost burdens on the treater and (2) facilitates implementation of the compliance and enforcement program.

3.3.5 Calculation of Standards

The final step in setting a performance standard is to define the maximum acceptable constituent levels in treatment residuals for the selected BDAT-list constituents for a particular waste treatability group, based on the performance of the BDAT technology. This is done by multiplying the average treatment value observed in the acceptable available data by a factor known as the "variability factor."

Only data developed at well-designed and well-operated systems are used to calculate performance standards. Parts or all of the available data sets may be discarded on a case-by-case basis. For instance, if the residence time for a waste during a particular test run was substantially shorter than the planned value, EPA might conclude that the system was not properly operated during that run and would discard the associated treatment results in calculating average treatment efficiencies.

The variability factor used to calculate performance standards takes into account that even well-designed and well-operated treatment systems will experience some fluctuations in performance. These fluctuations may result from inherent mechanical limitations in treatment control systems, treatability variations caused by changing influent loads, unavoidable variations in procedures for collecting treated samples, or variations in sample analysis. Setting treatment standards using a variability factor should therefore not be viewed as a relaxation of section 3004(m)'s requirements, but rather as a response to normal variations in treatment processes. As a practical matter, facilities will have to be designed to meet an average level of performance that is more stringent than the standard in order to ensure continuous compliance with the standard.

EPA calculates the variability factor for each selected constituent of concern using the statistical methods described in Appendix A. The equation is the same as that used for the development of numerous regulations in the Effluent Guidelines Program under the Clean Water Act. It sets the standard at the upper 99th percentile value concentration of the constituent expected in the treatment residual, using the mean and standard deviation calculated from the acceptable available data, and assuming that performance varies lognormally.

There is an additional step in the calculation of the treatment standards in those instances where the ANOVA test shows that more than one technology achieves a level of performance that represents BDAT. In such instances, EPA first averages the mean performance value for each

technology for each constituent of concern, and then multiplies that value by the highest variability factor among the technologies considered. This ensures that all BDAT technologies used as the basis of the standard will achieve full compliance.

3.4 Compliance with Performance Standards

Compliance with a treatment standard requires only that the treatment levels specified in the standard for each treatment residual be achieved prior to land disposal of these residuals. Performance standards do not, as noted above, require the use of any particular treatment method or technology. Dilution is prohibited as a means of complying with the standard; wastes that inherently meet the standard when generated may be land disposed.

Measurements of compliance with the standard should use the same procedures as those used to define BDAT, e.g., they can be based either on total constituent concentrations or on TCLP analyses of the treated waste.

3.5 BDAT Treatment Standards for "Derived-from" and "Mixed" Wastes

"Derived-from" wastes are wastes generated in the course of treating a listed waste. "Mixed" wastes are wastes generated by mixing of multiple listed wastes, or by mixing of a listed waste with a nonhazardous waste, in which case the mixture is considered to be entirely the listed waste. These classes of wastes raise several special issues.

3.5.1 Wastes from Treatments Generating Multiple Residues

Where the treatment technology or technology on which a performance standard is based generates residues incidental to treatment, these residues may be hazardous wastes in themselves and may require treatment prior to ultimate land disposal. The following considerations are relevant to such derived-from wastes:

1. All of the residues from treating the original listed wastes are likewise considered to be the listed waste by virtue of the derived-from rule contained in 40 CFR 261.3(c)(2). Consequently, all of the wastes generated in the course of treatment would be prohibited from land disposal unless they satisfy the treatment standard, or unless they meet one of the exceptions to the prohibition on land disposal.

2. The Agency's proposed treatment standards generally contain a concentration level for wastewaters (less than 1 percent total organic carbon and less than 1 percent total suspended solids*) and a concentration level for nonwastewaters (more than 1 percent total organic carbon and more than 1 percent total suspended solids). The treatment standards apply to all of the wastes generated in treating the original prohibited waste. Thus, all nonwastewaters generated from treating these wastes would have to meet the treatment standard for nonwastewaters; all wastewaters would have to meet standards for wastewaters. EPA wishes to make clear that this approach is not meant to allow partial treatment in order to comply with the applicable standards.

3. The Agency has not performed tests, in all cases, on every waste that can result from every part of a treatment process or system.

3.5.2 Mixtures and Other Derived-from Residues

Residues may occur from other types of management than treatment. An example is contaminated soil, or leachate, that is derived from managing the waste. In these cases, the mixture is still considered to be the

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* The term "total suspended solids" (TSS) clarifies EPA's previously used terminology of "total solids" and "filterable solids." Total suspended solids is measured by Method 209c (Total Suspended Solids Dried at 103 to 105 C) in Standard Methods for the Examination of Water and Wastewater (APHA, AWWA, and WPCF 1985).

listed waste, either because of the derived-from rule (40 CFR 261.3(c)(2)(i)) or the mixture rule (40 CFR 261.3(a)(2)(iii) and (iv)) or because the listed waste is contained in the matrix (see, for example, 40 CFR 261.33(d)). The prohibition for the particular listed waste consequently applies to this type of waste.

EPA believes that the majority of these residues can meet the treatment standards for the underlying listed wastes, with the possible exception of contaminated soil and debris, for which the Agency is currently investigating whether it is appropriate to establish a separate treatability subcategory. For the most part, these residues will be less concentrated than the original listed waste and therefore easier to treat to specified performance levels. In addition, the standards make a generous allowance for process variability by assuming that all treatability values used to establish the standard are lognormally distributed. The waste may also be amenable to a relatively nonvariable form of treatment, such as incineration.

Finally, and perhaps most important, the rules contain a treatability variance that allows petitioners to demonstrate that a particular waste cannot be treated to the level specified in the rule (40 CFR 268.44(a); see also Section 4). This provides an opportunity to demonstrate the appropriateness of different standards for unusual waste matrices.

3.5.3 Residues from Managing Listed Wastes or Wastes that Contain Listed Wastes

Residues from managing scheduled wastes (the First, Second, and Third Third wastes), the listed California List wastes, and spent solvent and

dioxin-containing wastes are all considered to be subject to the prohibitions for the underlying hazardous waste. Residues from managing California List wastes likewise are subject to the California List prohibitions when the residues themselves exhibit a characteristic of hazardous waste. This determination stems directly from the derived-from rule in 40 CFR 261.3(c)(2) or, in some cases, from the fact that the waste is mixed with, or otherwise contains, the listed waste. The underlying principle stated in all of these provisions is that listed wastes remain listed until delisted.

The Agency's historic practice in processing delisting petitions that address mixing residuals has been to consider them to be the listed waste, and to require that delisting petitioners address all constituents for which the derived-from waste (or other mixed waste) was listed. The language in 40 CFR 260.22(b) states that mixtures or derived-from residues can be delisted provided a delisting petitioner makes a demonstration identical to that which a delisting petitioner would make for the underlying waste. Consequently, these residues are treated as the underlying listed waste for delisting purposes. The statute likewise takes this position, indicating that soil and debris that are contaminated with listed spent solvents or dioxin wastes are subject to the prohibition for these wastes, even though these wastes are not the originally generated waste, but rather are a residual from its management (RCRA section 3004(e)(3)). It is EPA's view that all such residues are covered by the existing prohibitions and treatment standards for the

listed hazardous waste that these residues contain and from which they are derived.

3.6 Other Types of Standards: Technology-Based and "No Land Disposal"

In some circumstances it is not possible to develop concentration-based performance standards. The Agency then has two options: to set a standard based on a specific treatment method or to set a standard of "no land disposal."

If no acceptable data are available for a particular waste or waste group using the BDAT technology identified for that group, the Agency may decide to establish a technology-based standard rather than a performance standard. This may happen when an analytical procedure is not available to measure the constituent of concern or an appropriate surrogate of indicator constituent can not be identified to measure the treatment performance.

A standard establishing a standard of "no land disposal" for a waste group simply prohibits any further land disposal of that group. It sets no performance standards for treatment. "No land disposal" is appropriate when:

1. The waste group in question is no longer generated.
2. None of the waste currently generated is land disposed.
3. The technology exists for total recycling of wastes in the group.

4. VARIANCES FROM THE BDAT TREATMENT STANDARD

EPA recognizes that unique wastes may exist that cannot be treated to the level specified as the treatment standard. A particular waste may, for example, be significantly different from wastes considered in establishing treatability groups because it might be mixed with other waste streams through spills or other inadvertent mixing. This might alter its treatability such that it cannot meet the applicable treatment standard. In such a case, a generator or owner/operator may submit a petition to the Administrator requesting a variance from the treatment standard.

Variance petitions must demonstrate that the treatment standard established for a given waste cannot be met. This demonstration can be made by showing that attempts to treat the waste by available technologies were not successful, or by performing appropriate analyses of the waste that document that its characteristics affecting treatment performance are such that it cannot be treated to specified levels. Variances will not be granted based solely on a showing that adequate BDAT treatment capacity is unavailable.* The Agency will consider granting generic petitions provided that representative data are submitted to support a variance for each facility covered by the petition.

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* Such demonstrations can be made according to the provisions in Part 268.5 of RCRA for case-by-case extensions of the effective date of promulgated standards.

Petitioners should submit at least one copy to:

The Administrator
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, DC 20460

An additional copy marked "Treatability Variance" should be submitted to:

Chief, Waste Treatment Branch
Office of Solid Waste (WH-565)
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, DC 20460

Petitions containing confidential information should be sent with only the inner envelope marked "Treatability Variance" and "Confidential Business Information" and with the contents marked in accordance with the requirements of 40 CFR 2 (41 FR 36902, September 1, 1976, amended by 43 FR 4000).

The petition should contain the following information:

1. The petitioner's name and address.

2. A statement of the petitioner's interest in the proposed action.

3. The name, address, and EPA identification number of the facility generating the waste, and the name and telephone number of the plant contact.

4. The process(es) and feed materials generating the waste and an assessment of whether such process(es) or feed materials may produce a waste that is not covered by the demonstration.

5. A description of the waste sufficient for comparison with the waste considered by the Agency in developing BDAT, and an estimate of the average and maximum monthly and annual quantities of waste covered by the demonstration. (NOTE: the petitioner should consult the appropriate BDAT background document to determine the characteristics of the wastes considered in developing treatment standards.)

6. If the waste has been treated, a description of the system used for treating the waste, including the process design and operating conditions. The petition should include the reasons why the treatment standards are not achievable and/or why the petitioner believes that the standards are based on inappropriate technology for treating the waste. (NOTE: the petitioner should refer to the appropriate BDAT background document as guidance for determining the design and operating parameters that the Agency used in developing treatment standards.

7. A description of the alternative treatment systems examined by the petitioner (if any); a description of the treatment system deemed appropriate by the petitioner for the waste in question; and, if appropriate, the concentrations in the treatment residual or extract of the treatment residual (i.e., using the TCLP, where appropriate, for stabilized metals) that can be achieved by applying such treatment to the waste.

8. A description of those parameters affecting treatment selection and waste characteristics that affect performance, including results of all analyses. (See Treatment Technology Background Document for a discussion of waste characteristics affecting performance that the Agency has identified for the technology representing BDAT.)

9. The dates of the sampling and testing.

10. A description of the methodologies and equipment used to obtain representative samples.

11. A description of the sample handling and preparation techniques, including techniques used for extraction, containerization, and preservation of the samples.

12. A description of the analytical procedures used, including QA/QC methods.

After receiving a petition for a variance, the Administrator may request additional information or waste samples that may be required to evaluate and process the petition. In addition, all petitioners must certify that the information provided to the Agency is accurate under 40 CFR 268.4 (b).

In determining whether a variance will be granted, the Agency will first look at the design and operation of the treatment system being used. If it determines that the technology and operation are consistent with BDAT, it will evaluate the waste to determine if the waste matrix and/or its physical parameters are such that the BDAT treatment standards reflect treatment of this waste. Essentially, this latter analysis will concern the parameters affecting treatment selection and waste characteristics affecting treatment performance.

In cases where BDAT is based on more than one technology, the petitioner will need to demonstrate that the treatment standard cannot be met using any of the technologies, or that none of the technologies is appropriate for treatment of the waste. After the Agency has made a determination on the petition, the Agency's findings will be publisned in the Federal Register, followed by a 30-day period for public comment. After review of the public comments, EPA will publish its final determination in the Federal Register as an amendment to the treatment standards in 40 CFR 268, Subpart D.

5. P AND U WASTES

P and U category hazardous wastes include discarded commercial chemical products, off-specification species, container residues, and spills residues associated with any of these; each is listed in terms of a single chemical constituent. EPA defines P wastes as "acute hazardous" wastes and U wastes as "toxic" wastes.

P and U wastes pose special problems for the development of treatment standards for four reasons:

1. Although P and U wastes are listed as single chemical constituents, their composition may vary substantially, either because the waste may be an off-specification product or because it may become mixed with other substances--hazardous and nonhazardous--during a spill.

2. There are 230 P and U wastes in all. It is therefore rare to find acceptable treatment data on specific listed categories.

3. EPA does not have analytical methods that are approved by the Office of Solid Waste for many P and U wastes.

4. Some P and U constitutents may either react or degrade in the presence of water or other leaching solutions, preventing the direct measurement of the P or U constituent in treatment residues. EPA therefore considers the possibility of using reaction or degradation products to develop treatment performance standards for these wastes, but in some instances appropriate indicator compounds may not exist.

EPA's general approach to developing standards for P and U wastes is to assign them to treatability groups and to transfer data and standards from similar wastes. Distinctions between "acute hazardous" (P) wastes and "toxic" (U) wastes generally have no bearing on their treatability, so they do not contribute to the development of the treatability groups identified in this section.

As for other wastes, treatment for P and U wastes may be stated in terms of numerical performance standards, but, to respond to the problems listed above, the Agency may sometimes specify methods of treatment (such as incineration) rather than levels of treatment performance. EPA also believes that recycling may be feasible for some of the P and U wastes: some off-specification products might be required to undergo further onsite processing; others might require treatment prior to recycling.

EPA's strategy is to define P and U treatability groups based on similarities in elemental composition (e.g., carbon, halogens, and metals) and the presence of key functional groups (e.g., phenolics, esters, and amines) within the structure of the individual P or U constituent. The Agency also considers physical and chemical factors that are known to affect the selection of treatment alternatives and to affect the performance of treatment--examples include volatility and solubility.

The eight treatability groups for P and U wastes are:

1. Halogenated organic wastes
2. Organo-nitrogen and organo-sulfur wastes
3. Wastes of a pharmaceutical nature
4. Reactive wastes
5. Combustible wastes (other than wastes in the above categories)
6. Gaseous wastes
7. Metal-containing wastes
8. Other P and U wastes.

5.1 Halogenated Organic Wastes

Within this general group, EPA tentatively expects to develop six separate standards for subgroups defined primarily in terms of similarity of chemical structure, common industrial use or generation, and functional similarity. The subgroups are:

- Chlorinated aliphatics
- Chlorinated phenols
- Single-component halogenated pesticides
- Multiple-component halogenated pesticides
- Chloro-benzene wastes
- Miscellaneous halogenated organic wasetes.

Table 5-1 lists the P and U wastes falling under each of the above six subgroups.

5.2 Organo-Nitrogen and Organo-Sulfur Wastes

Within this general group, EPA tentatively expects to develop five separate standards for subgroups defined primarily in terms of similarity of chemical structure, common industrial use or generation, and functional similarity. The subgroups are:

- Nonhalogenated pesticides
- Nitro-organics
- Amines
- Nitriles and other nitro-organics
- Organo-sulfur wastes.

Table 5-2 lists the P and U wastes falling under each of the above five subgroups.

5.3 Wastes of a Pharmaceutical Nature

The Agency believes that most of the P and U wastes included within this group are wastes related to experimental drugs that were never produced in volume. Table 5-3 shows the wastes listed within this group.

Table 5-1 Halogenated Organic Wastes

Chlorinated Aliphatic Wastes

U044 - Chloroform
U074 - 1,4-Dichloro-2-butene
U076 - 1,1-Dichloroethane
U077 - 1,2-Dichloroethane
U078 - 1,1-Dichloroethylene
U079 - 1,2-Dichloroethylene
U080 - Methylene chloride
U083 - 1,2-Dichloropropane
U084 - 1,3-Dichloropropene
U131 - Hexachloroethane
U184 - Pentachloroethane
U208 - 1,1,1,2-Tetrachloroethane
U209 - 1,1,2,2-Tetrachloroethane
U210 - Tetrachloroethylene
U211 - Carbon tetrachloride
U226 - 1,1,1-Trichloroethane
U227 - 1,1,2-Trichloroethane
U228 - Trichloroethylene
U243 - Hexachloropropene

Chlorinated Phenolic Wastes

U039 - p-Chloro-m-cresol
U048 - 2-Chlorophenol
U081 - 2,4-Dichlorophenol
U082 - 2,6-Dichlorophenol
U240 - 2,4-D salts and esters

Single Component Halogenated Pesticide Wastes

F004 - Aldrin
P037 - Dieldrin
P050 - Endosulfan
P051 - Endrin
P057 - 2-Flouroacetamide
P058 - Fluoracetic acid, sodium salt
P059 - Heptachlor
P060 - Isodrin
U038 - Chlorobenzilate
U060 - DDD
U061 - DDT

Table 5-1 (continued)

Single Component Halogenated Pesticide Wastes (continued)

U062 - Diallate
U066 - 1,2-Dibromo-3-chloropropane
U097 - Dimethylcarbamyl chloride
U128 - Hexachlorobutadiene
U129 - Lindane
U130 - Hexachlorocyclopentadiene
U132 - Hexachlorophene
U142 - Kepone
U185 - Pentachloronitrobenzene
U247 - Methoxychlor

Multiple Component Halogenated Pesticide Wastes

P123 - Toxaphene
U036 - Chlordane, technical

Chlorobenzene Wastes

U037 - Chlorobenzene
U070 - 1,2-Dichlorobenzene
U071 - 1,3-Dichlorobenzene
U072 - 1,4-Dichlorobenzene
U183 - Pentachlorobenzene
U207 - 1,2,4,5-Tetrachlorobenzene
U127 - Hexachlorobenzene

Miscellaneous Halogenated Organic Wastes

P016 - bis-(Chloromethyl) ether
P017 - Bromoacetone
P023 - Chloroacetaldehyde
P024 - p-Chloroaniline
P026 - 1-(o-Chlorophenyl) thiourea
P027 - 3-Chloropropionitrile
P028 - Benzyl chloride
P118 - Trichloromethanethiol
U006 - Acetyl chloride
U017 - Benzal chloride
U020 - Benzenesulfonyl chloride
U024 - bis-(2-Chloroethoxy) methane
U025 - Dichloroethyl ether

Table 5-1 (continued)

Miscellaneous Halogenated Organic Wastes (continued)

U026 - Chloronaphazine
U027 - bis-(2-Chloroispropyl) ether
U030 - 4-Bromophenyl phenyl ether
U034 - Trichloroacetaldehyde
U041 - n-Chloro-2,3-epoxypropane
U042 - 2-Chloroethyl vinyl ether
U046 - Chloromethyl methyl ether
U047 - 2-Chloronaphthalene
U049 - 4-Chloro-o-toluidine hydrochloride
U067 - Ethylene dibromide
U068 - Dibromomethane
U073 - 3,3'-Dichlorobenzidine
U138 - Iodomethane
U156 - Methyl chlorocarbonate
U158 - 4,4-Methylene-bis-(2-chloroaniline)
U192 - Pronamide
U222 - o-Toluidine hydrochloride
U225 - Bromoform

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Table 5-2. Organo-Nitrogen and Organo-Sulfur Wastes

Nonhalogenated Pesticide Wastes

P001 - Warfarin (>0.3%)
P018 - Brucine
P020 - Dinoseb
P045 - Thiofanox
P066 - Methomyl
P070 - Aldicarb
P072 - 1-Naphthyl-2-thiourea (Bantu)
P088 - Endothall
U011 - Amitrole
U014 - Auramine
U114 - Ethylene bis-dithiocarbamic acid
U244 - Thiram
U248 - Warfarin (<0.3%)

Nitro-Organics

P034 - 2-Cyclohexyl-4,6-dinitrophenol
P047 - 4,6-Dinitro-o-cresol and salts
P048 - 2,4-Dinitrophenol
P069 - Methyllactonitrile
P077 - p-Nitroaniline
U105 - 2,4-Dinitrotoluene
U106 - 2,6-Dinitrotoluene
U169 - Nitrobenzene
U170 - 4-Nitrophenol
U171 - 2-Nitropropane
U181 - 5-Nitro-o-toluidine
U234 - sym-Trinitrobenzene

Amines

P046 - a,a-Dimethylphenethylamine
P082 - N-Nitrosodimethylamine
P084 - N-Nitrosomethylvinylamine
U012 - Aniline
U021 - Benzidine
U091 - 3,3'-Dimethoxybenzidine
U092 - Dimethyl amine
U093 - p-Dimethylaminoazobenzene
U095 - 3,3'-Dimethylbenzidine
U110 - Dipropylamine
U111 - Di-n-propylnitrosoamine
U167 - 1-Naphthylamine

2374g

Table 5-2. Organo-Nitrogen and Organo-Sulfur Wastes

Nonhalogenated Pesticide Wastes

P001 - Warfarin (>0.3%)
P018 - Brucine
P020 - Dinoseb
P045 - Thiofanox
P066 - Methomyl
P070 - Aldicarb
P072 - 1-Naphthyl-2-thiourea (Bantu)
P088 - Endothall
U011 - Amitrole
U014 - Auramine
U114 - Ethylene bis-dithiocarbamic acid
U244 - Thiram
U248 - Warfarin (<0.3%)

Nitro-Organics

P034 - 2-Cyclohexyl-4,6-dinitrophenol
P047 - 4,6-Dinitro-o-cresol and salts
P048 - 2,4-Dinitrophenol
P069 - Methyllactonitrile
P077 - p-Nitroaniline
U105 - 2,4-Dinitrotoluene
U106 - 2,6-Dinitrotoluene
U169 - Nitrobenzene
U170 - 4-Nitrophenol
U171 - 2-Nitropropane
U181 - 5-Nitro-o-toluidine
U234 - sym-Trinitrobenzene

Amines

P046 - a,a-Dimethylphenethylamine
P082 - N-Nitrosodimethylamine
P084 - N-Nitrosomethylvinylamine
U012 - Aniline
U021 - Benzidine
U091 - 3,3'-Dimethoxybenzidine
U092 - Dimethyl amine
U093 - p-Dimethylaminoazobenzene
U095 - 3,3'-Dimethylbenzidine
U110 - Dipropylamine
U111 - Di-n-propylnitrosoamine
U167 - 1-Naphthylamine

Table 5-2. (continued)

Amines

U168 - 2-Naphthylamine
U172 - N-Nitroso-di-n-butylamine
U173 - N-Nitroso-diethanolamine
U174 - N-Nitroso-diethylamine
U179 - N-Nitrosopiperidine
U180 - N-Nitrosopyrrolidine
U191 - 2-Picoline
U194 - n-Propylamine
U196 - Pyridine

Nitriles and Other Nitro-Organics

P064 - Isocyanic acid, methyl ester
P101 - Propanenitrile/ethyl cyanide
U003 - Acetonitrile
U148 - Maleic hydrazide
U149 - Malonitrile
U176 - N-Nitroso-N-ethylurea
U177 - N-Nitroso-N-methylurea
U178 - N-Nitroso-N-methylurethane
U236 - Trypan blue
U238 - Ethyl carbamate

Organosulfur Wastes

P002 - 1-Acetyl 2-thiourea
P014 - Benzene thiol (Thiophenol)
P022 - Carbon disulfide
P049 - 2,4-Dithiobiuret
P093 - N-Phenylthiourea
P116 - Thiosemicarbazide
U116 - Ethylene thiourea
U119 - Ethyl methane sulfonate
U193 - 1,3-Propane sultone
U218 - Thioacetamide
U219 - Thiourea

Table 5-3. Wastes of a Pharmaceutical Nature

P007 - Muscimol (5-Aminoethyl 3-isoxazolol)
P008 - 4-Aminopyridine
P042 - Epinephrine
P075 - Nicotine and salts
P108 - Strychnine and salts
U010 - Mitomycin C
U015 - Azaserine
U035 - Chlorambucil
U059 - Daunomycin
U089 - Diethyl stilbestrol
U090 - Dihydrosafrole
U141 - Isosafrole
U143 - Lasiocarpine
U150 - Melphalan
U155 - Methapyrilene
U163 - N-Methyl N-nitro N-nitroguanidine
U164 - Methylthiouracil
U187 - Phenacetin
U200 - Reserpine
U202 - Saccharin and salts
U203 - Safrole
U206 - Streptozotocin
U237 - Uracil mustard

5.4 Reactive Wastes

These wastes are either highly reactive or explosive, or they are polymers that also tend to be highly reactive. Table 5-4 shows the pertinent subcategories within this group.

5.5 Gaseous Wastes

The P and U wastes listed in Table 5-5 are typically encountered as gases and are therefore unlikely to exist as spill residues. Although these compounds may exist in aqueous or organic solutions, the solutions are not considered to be the listed P or U waste.

5.6 Combustible Wastes (other than those listed under 5-1 through 5-5 above)

Incineration is the treatment method selected for all wastes in this category. Many of these wastes have very high Btu values and are therefore potentially suitable as fuel substitutes, although this may not always be possible because some of these wastes are highly toxic. Within this general category, EPA has identified two subgroups: (1) aromatic and polycyclic hydrocarbon wastes and (2) oxygenated hydrocarbon wastes. These subgroups are shown within the general listing on Table 5-6.

5.7 Metal-containing Wastes

This treatability group, shown on Table 5-7, covers wastes predominantly containing metallic compounds, including metallic salts, organo-metallics, and bimetallic compounds.

Table 5-4. Reactive Wastes

Polymeric Wastes

P003 - Acrolein
P005 - Allyl alcohol
P054 - Ethyleneimine (Aziridine)
P067 - 2-Methylaziridine
P102 - Propargyl alcohol
U007 - Acrylamide
U008 - Acrylic acid
U009 - Acrylonitrile
U053 - Crotonaldehyde
U113 - Ethyl acrylate
U118 - Ethyl methacrylate
U152 - Methacrylonitrile
U162 - Methyl methacrylate
U186 - 1,3-Pentadiene
U22. - Toluenediamine
U223 - Toluene diisocyanate

Explosive or Highly Reactive Wastes

P006 - Aluminum phosphide
P009 - Ammonium picrate
P015 - Beryllium dust
P068 - Methyl hydrazine
P073 - Nickel carbonyl
P081 - Nitroglycerin
P087 - Osmium tetroxide
P105 - Sodium azide
P107 - Strontium sulfide
P112 - Tetranitromethane
P122 - Zinc phosphide (>10%)
U023 - Benzotrichloride
U086 - N,N-Diethylhydrazine
U096 - a,a-Dimethyl benzyl hydroperoxide
U098 - 1,1-Dimethylhydrazine
U099 - 1,2-Dimethylhydrazine
U103 - Dimethyl sulfate
U109 - 1,2-Diphenylhydrazine
U133 - Hydrazine
U189 - Phosphorus sulfide
U249 - Zinc phosphide (<10%)

Table 5-5. Gaseous Wastes

Gaseous Treatability Group
P031 - Cyanogen
P033 - Cyanogen Chloride
P056 - Fluorine
P076 - Nitric oxide
P033 - Cyarogen chloride
P078 - Nitrogen dioxide
P095 - Phosgene
P096 - Phosphine
U029 - Methyl bromide
U033 - Carbonyl fluoride
U043 - Vinyl chloride
U045 - Chloromethane
U075 - Dichlorodifluoromethane
U115 - Ethylene oxide
U121 - Fluorotrichloromethane
U134 - Hydrofluoric acid
U135 - Hydrogen sulfide
U153 - Methanethiol
U246 - Cyanogen bromide

Table 5-6. Combustible Wastes

Aromatic and Polycyclic Hydrocarbon Wastes

U005 - 2-Acetylaminofluorene
U016 - Benz(c)acridine
U018 - Benz(a)anthracene
U019 - Benzene
U022 - Benzo(a)pyrene
U050 - Chrysene
U055 - Cumene (isopropylbenzene)
U056 - Cyclohexane
U063 - Dibenzo(a,h)anthracene
U064 - 1,2:7,8 Dibenzopyrene
U094 - 7,12-Dimethyl benz[a]anthracene
U120 - Fluoranthene
U137 - Indeno(1,2,3-c,d)pyrene
U157 - 3-Methylcholanthrene
U165 - Naphthalene
U220 - Toluene (methyl benzene)
U239 - Xylenes (dimethyl benzenes)

Oxygenated Hydrocarbon Wastes

U001 - Acetaldehyde
U002 - Acetone
U004 - Acetophenone
U031 - n-Butanol
U051 - Creosote
U052 - Cresols
U057 - Cyclohexanone
U085 - 1,2:3,4-Diepoxybutane
U101 - 2,4-Dimethylphenol
U108 - 1,4-Dioxane
U112 - Ethyl acetate
U117 - Ethyl ether
U122 - Formaldehyde
U123 - Formic acid
U124 - Furan
U125 - Furfural
U126 - Glycidaldehyde
U140 - Isobutanol
U147 - Maleic anhydride
U154 - Methanol
U159 - Methyl ethyl ketone
U160 - Methyl ethyl ketone peroxide
U161 - Methyl isobutyl ketone
U166 - 1,4-Naphthoquinone
U182 - Paraldehyde
U188 - Phenol
U197 - p-Benzoquinone
U201 - Resorcinol
U213 - Tetrahydrofuran

Table 5-7. Metal-Containing Wastes

P010 - Arsenic acid
P011 - Arsenic (V) oxide
P012 - Arsenic (III) oxide
P036 - Dichlorophenylarsine
P038 - Diethylarsine
P065 - Mercury Fulminate
P092 - Phenylmercuric acetate
P103 - Selenourea
P110 - Tetraethyl lead
P113 - Thallic oxide
P114 - Thallium Selenite
P115 - Thallium (I) sulfate
P119 - Ammonium vanadate
P120 - Vanadium pentoxide
U032 - Calcium chromate
U136 - Cacodylic acid
U144 - Lead acetate
U145 - Lead phosphate
U146 - Lead subacetate
U151 - Mercury
U204 - Selenious acid
U205 - Selenium disulfide
U214 - Thallium (I) acetate
U215 - Thallium (I) carbonate
U216 - Thallium (I) chloride
U217 - Thallium (I) nitrate

5.8 Other P and U Wastes

P and U wastes other than those listed in Section 5.1 through 5.7 above are being regulated along with similar F and K wastes.

Specifically:

- Cyanide-containing P and U wastes are being regulated with the listed wastes F007 through F012 and F019 (which are listed primarily because of their cyanide content).
- Phthalate-containing P and U wastes are being regulated with K023, K094, and K095.
- Organophosphorous P and U wastes are being regulated with K038, K039, and K040.
- P and U wastes from the production of toluene diamine and toluene diisocyanate are being regulated with K027 and K111 through K116.

Table 5-8 shows all P and U wastes that have already been regulated as stated above.

Table 5-8. Other P and U Wastes

Phthalate Containing Wastes

U028 - Bis(2-ethylhexyl)phthalate
U069 - Di-n-butyl phthalate
U088 - Diethyl phthalate
U102 - Dimethyl phthalate
U107 - Di-n-octyl phthalate
U190 - Phthalic anhydride

Organophosphorous Wastes

P039 - Disulfoton
P040 - Diethyl 2-pyrazinyl phosphorothioate
P041 - Diethyl-p-nitrophenyl phosphate
P043 - Diisopropyl fluorophosphate
P044 - Dimethoate
P062 - Hexaethyl tetraphosphate
P071 - Methyl parathion
P085 - Octamethyl pyrophosphoramide
P089 - Parathion
P094 - Phorate
P097 - Famphur
P109 - Tetraethyl dithiopyrophosphate
P111 - Tetraethyl pyrophosphate
U058 - Cyclophosphamide
U087 - O,O-Diethyl S-methyl dithiophosphate
U235 - tris-(2,3-dibromopropyl) phosphate

Cyanide Containing Wastes

P013 - Barium cyanide
P021 - Calcium cyanide
P029 - Copper cyanide
P030 - Soluble cyanide salts
P063 - Hydrogen cyanide
P074 - Nickel cyanide
P098 - Potassium cyanide
P099 - Potassium silver cyanide
P104 - Silver cyanide
P106 - Sodium cyanide
P121 - Zinc cyanide

Table 5-8. Other P and U Wastes

Wastes from the Production of Toluene Diamine and Toluene Diisocyanate

U221 - Toluenediamine
U223 - Toluene diisocyanate

APPENDIX A

STATISTICAL METHODS

A-1. Accuracy Correction of Sampled Data

To calculate treatment standards, it is first necessary to adjust laboratory results for accuracy, based on the laboratory test's "recovery value" for each constituent it analyzes.* The recovery value measures the amount of constituent recovered after "spiking"--the addition to the waste sample of a known amount of constituent. The recovery value is equal to the amount of constituent recovered after spiking, minus the initial concentration in the sample, divided by the amount recovered.

Once the recovery value is determined, the following procedures are used to select the appropriate percent recovery value to adjust the analytical data:

1. If duplicate spike recovery values are available for the constituent of interest, the data are adjusted by the lowest available percent recovery value--the value that will yield the most conservative estimate of treatment achieved. (If a spike recovery value of less than 20 percent is reported for a specific constituent, however, the data cannot be used to set a national treatment standard and are discarded.)

2. If data are not available for a specific constituent, but are available for an isomer, then the spike recovery data are transferred from the isomer and the data are adjusted using the percent recovery selected, according the procedure described in (1) above.

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* It may also be necessary to estimate recovery values in order to perform the ANOVA test discussed in Section 3.2 to determine which demonstrated technologies are "best."

3. If data are not available for a specific constituent, but are available for a similar class of constituents, then spike recovery values for this class of constituents are transferred. All spike recovery values greater than or equal to 20 percent for a spiked sample are averaged, and the constituent concentration is adjusted by the average recovery value. If spiked recovery data are available for more than one sample, the average is calculated for each sample and the data are adjusted by the lowest average value.

4. If spike recovery data are not available for the waste matrix, then spike recovery values are transferred from a waste that the Agency believes is a similar matrix. For instance, if the data are for an ash resulting from incineration, then data from other incinerator ashes could be used. This is not an exact analysis, but it is considered the best practical approach. In assessing the recovery data to be transferred, the procedures outline in (1), (2), and (3) above are followed.

The analytical procedures employed to generate the data used to calculate each treatment standard for tested wastes are provided in the background document prepared for that waste. Any alternatives or equivalent procedures and/or equipment allowed by the approved methods will also be documented in EPA's SW-846, Third Edition (November 1986).

NOTE: The Agency will use the methods and procedures presented in each background document to enforce the treatment standards. Facilities should therefore use these procedures in assessing the performance of their treatment systems.

A.2 F Value Determination for ANOVA Test

As noted earlier in Section 1.2, EPA is using the statistical method known as analysis of variance (ANOVA) to determine the level of performance that represents "best" treatment where more than one technology is demonstrated. This method provides a measure of the differences between data sets.

If the Agency found that the levels of performance for one or more technologies are not statistically different (i.e., the data sets are homogeneous). EPA would average the long-term performance values achieved by each technology and then multiply this value by the largest variability factor associated with any of the acceptable technologies. If EPA found that one technology performs significantly better (i.e., the data sets are not homogeneous), the "best" technology would be the technology that achieves the best level of performance, i.e., the technology with the lowest mean value.

To determine whether any or all of the treatment performance data sets are homogeneous using the analysis of variance method, it is necessary to compare a calculated "F value" to what is known as a "critical value." (See Table A-1.) These critical values are available in most statistics texts (see, for example, Statistical Concepts and Methods by Bhattacharyya and Johnson, 1977, John Wiley Publications, New York).

Where the F value is less than the critical value, all treatment data sets are homogeneous. If the F value exceeds the critical value, it is necessary to perform a "pair wise F" test to determine whether any of the sets are homogeneous. The "pair wise F" test must be done for all of the various combinations of data sets using the same method and equation as the general F test.

95th PERCENTILE VALUES FOR THE *F* DISTRIBUTION

n_1 = degrees of freedom for numerator
n_2 = degrees of freedom for denominator
(shaded area = .95)

$n_1 = k-1 \qquad n_2 = N-k$

n_2 \ n_1	1	2	3	4	5	6	8	12	16	20	30	40	50	100	∞
1	161.4	199.5	215.7	224.6	230.2	234.0	238.9	243.9	246.3	248.0	250.1	251.1	252.2	253.0	254.3
2	18.51	19.00	19.16	19.25	19.30	19.33	19.37	19.41	19.43	19.45	19.46	19.46	19.47	19.49	19.50
3	10.13	9.55	9.28	9.12	9.01	8.94	8.85	8.74	8.69	8.66	8.62	8.60	8.58	8.56	8.53
4	7.71	6.94	6.59	6.39	6.26	6.16	6.04	5.91	5.84	5.80	5.75	5.71	5.70	5.66	5.63
5	6.61	5.79	5.41	5.19	5.05	4.95	4.82	4.68	4.60	4.56	4.50	4.46	4.44	4.40	4.36
6	5.99	5.14	4.76	4.53	4.39	4.28	4.15	4.00	3.92	3.87	3.81	3.77	3.75	3.71	3.67
7	5.59	4.74	4.35	4.12	3.97	3.87	3.73	3.57	3.49	3.44	3.38	3.34	3.32	3.28	3.23
8	5.32	4.46	4.07	3.84	3.69	3.58	3.44	3.28	3.20	3.15	3.08	3.05	3.03	2.98	2.93
9	5.12	4.26	3.86	3.63	3.48	3.37	3.23	3.07	2.98	2.93	2.86	2.82	2.80	2.76	2.71
10	4.96	4.10	3.71	3.48	3.33	3.22	3.07	2.91	2.82	2.77	2.70	2.67	2.64	2.59	2.54
11	4.84	3.98	3.59	3.36	3.20	3.09	2.95	2.79	2.70	2.65	2.57	2.53	2.50	2.45	2.40
12	4.75	3.89	3.49	3.26	3.11	3.00	2.85	2.69	2.60	2.54	2.46	2.42	2.40	2.35	2.30
13	4.67	3.81	3.41	3.18	3.03	2.92	2.77	2.60	2.51	2.46	2.38	2.34	2.32	2.26	2.21
14	4.60	3.74	3.34	3.11	2.96	2.85	2.70	2.53	2.44	2.39	2.31	2.27	2.24	2.19	2.13
15	4.54	3.68	3.29	3.06	2.90	2.79	2.64	2.48	2.39	2.33	2.25	2.21	2.18	2.12	2.07
16	4.49	3.63	3.24	3.01	2.85	2.74	2.59	2.42	2.33	2.28	2.20	2.16	2.13	2.07	2.01
17	4.45	3.59	3.20	2.96	2.81	2.70	2.55	2.38	2.29	2.23	2.15	2.11	2.08	2.02	1.96
18	4.41	3.55	3.16	2.93	2.77	2.66	2.51	2.34	2.25	2.19	2.11	2.07	2.04	1.98	1.92
19	4.38	3.52	3.13	2.90	2.74	2.63	2.48	2.31	2.21	2.15	2.07	2.02	2.00	1.94	1.88
20	4.35	3.49	3.10	2.87	2.71	2.60	2.45	2.28	2.18	2.12	2.04	1.99	1.96	1.90	1.84
22	4.30	3.44	3.05	2.82	2.66	2.55	2.40	2.23	2.13	2.07	1.98	1.93	1.91	1.84	1.78
24	4.26	3.40	3.01	2.78	2.62	2.51	2.36	2.18	2.09	2.03	1.94	1.89	1.86	1.80	1.73
26	4.23	3.37	2.98	2.74	2.59	2.47	2.32	2.15	2.05	1.99	1.90	1.85	1.82	1.76	1.69
28	4.20	3.34	2.95	2.71	2.56	2.45	2.29	2.12	2.02	1.96	1.87	1.81	1.78	1.72	1.65
30	4.17	3.32	2.92	2.69	2.53	2.42	2.27	2.09	1.99	1.93	1.84	1.79	1.76	1.69	1.62
40	4.08	3.23	2.84	2.61	2.45	2.34	2.18	2.00	1.90	1.84	1.74	1.69	1.66	1.59	1.51
50	4.03	3.18	2.79	2.56	2.40	2.29	2.13	1.95	1.85	1.78	1.69	1.63	1.60	1.52	1.44
60	4.00	3.15	2.76	2.53	2.37	2.25	2.10	1.92	1.81	1.75	1.65	1.59	1.56	1.48	1.39
70	3.98	3.13	2.74	2.50	2.35	2.23	2.07	1.89	1.79	1.72	1.62	1.56	1.53	1.45	1.35
80	3.96	3.11	2.72	2.48	2.33	2.21	2.05	1.88	1.77	1.70	1.60	1.54	1.51	1.42	1.32
100	3.94	3.09	2.70	2.46	2.30	2.19	2.03	1.85	1.75	1.68	1.57	1.51	1.48	1.39	1.28
150	3.91	3.06	2.67	2.43	2.27	2.16	2.00	1.82	1.71	1.64	1.54	1.47	1.44	1.34	1.22
200	3.89	3.04	2.65	2.41	2.26	2.14	1.98	1.80	1.69	1.62	1.52	1.45	1.42	1.32	1.19
400	3.86	3.02	2.62	2.39	2.23	2.12	1.96	1.78	1.67	1.60	1.49	1.42	1.38	1.28	1.13
∞	3.84	2.99	2.60	2.37	2.21	2.09	1.94	1.75	1.64	1.57	1.46	1.40	1.32	1.24	1.00

Table A-1 95th Percentile Values for the F Distribution

The F value is calculated as follows:

(i) All data are natural logtransformed.

(ii) The sum of the data points for each data set is computed (T_i).

(iii) The statistical parameter known as the sum of the squares between data sets (SSB) is computed:

$$SSB = \left[\sum_{i=1}^{k} \left(\frac{T_i^2}{n_i} \right) \right] - \left(\left[\frac{\sum_{i=1}^{k} T_i}{N} \right]^2 \right)$$

where:

k = number of treatment technologies
n_i = number of data points for technology i
N = number of data points for all technologies
T_i = sum of natural logtransformed data points for each technology.

(iv) The sum of the squares within data sets (SSW) is computed:

$$SSW = \left[\sum_{i=1}^{k} \sum_{j=1}^{n_i} x^2_{i,j} \right] - \sum_{i=1}^{k} \left(\frac{T_i^2}{n_i} \right)$$

where:

$x_{i,j}$ = The natural logtransformed observations (j) for treatment technology (i).

(v) The degrees of freedom corresponding to SSB and SSW are calculated. For SSB, the degree of freedom is given by k-1. For SSW, the degree of freedom is given by N-k.

(vi) Using the above parameters, the F value is calculated as follows:

$$F = \frac{MSB}{MSW}$$

where:

MSB = SSB/(k-1) and
MSW = SSW/(N-k).

A computational table summarizing the above parameters is shown below.

Computational Table for the F Value

Source	Degrees of freedom	Sum of squares	Mean square	F
Between	k-1	SSB	MSB = SSB/k-1	MSB/MSW
Within	N-k	SSW	MSW = SSW/N-k	

Below are three examples of the ANOVA calculation. The first two represent treatment by different technologies that achieve statistically similar treatment; the last example represents a case where one technology achieves significantly better treatment than the other technology.

Example 1
Methylene Chloride

Steam stripping				Biological treatment			
Influent (µg/l)	Effluent (µg/l)	ln(effluent)	[ln(effluent)]^2	Influent (µg/l)	Effluent (µg/l)	ln(effluent)	[illegible]
1550.00	10.00	2.30	5.29	1960.00	10.00	2.30	5.29
1290.00	10.00	2.30	5.29	2568.00	10.00	2.30	5.29
1640.00	10.00	2.30	5.29	1817.00	10.00	2.30	5.29
5100.00	12.00	2.48	6.15	1640.00	26.00	3.26	10.63
1450.00	10.00	2.30	5.29	3907.00	10.00	2.30	5.29
4600.00	10.00	2.30	5.29				
1760.00	10.00	2.30	5.29				
2400.00	10.00	2.30	5.29				
4800.00	10.00	2.30	5.29				
12100.00	10.00	2.30	5.29				
Sum: -	-	23.18	53.76	-	-	12.46	31.79
Sample Size: 10	10	10	-	5	5	5	-
Mean: 3669	10.2	2.32	-	2378	13.2	2.49	-
Standard Deviation: 3328.67	.63	.06	-	923.04	7.15	.43	-
Variability Factor:	1.15	-	-	-	2.48	-	-

ANOVA Calculations:

$$SSB = \left[\sum_{i=1}^{k} \left(\frac{T_i^2}{n_i} \right) \right] - \left[\frac{\left(\sum_{i=1}^{k} T_i \right)^2}{N} \right]$$

$$SSW = \left[\sum_{i=1}^{k} \sum_{j=1}^{n_i} x^2_{i,j} \right] - \sum_{i=1}^{k} \left(\frac{T_i^2}{n_i} \right)$$

$$MSB = SSB/(k-1)$$

$$MSW = SSW/(N-k)$$

Example 1 (Continued)

F = MSB/MSW

where:

k = number of treatment technologies

n_i = number of data points for technology i

N = number of natural logtransformed data points for all technologies

T_i = sum of logtransformed data points for each technology

X_{ij} = the nat. logtransformed observations (j) for treatment technology (i)

$n_1 = 10$, $n_2 = 5$, $N = 15$, $k = 2$, $T_1 = 23.18$, $T_2 = 12.46$, $T = 35.64$, $T^2 = 1270.21$

$T_1^2 = 537.31$ $T_2^2 = 155.25$

$$SSB = \left(\frac{537.31}{10} + \frac{155.25}{5}\right) - \frac{1270.21}{15} = 0.10$$

$$SSW = (53.76 + 31.79) - \left(\frac{537.31}{10} + \frac{155.25}{5}\right) = 0.77$$

MSB = 0.10/1 = 0.10

MSW = 0.77/13 = 0.06

$$F = \frac{0.10}{0.06} = 1.67$$

ANOVA Table

Source	Degrees of freedom	SS	MS	F value
Between(B)	1	0.10	0.10	1.67
Within(W)	13	0.77	0.06	

The critical value of the F test at the 0.05 significance level is 4.67. Since the F value is less than the critical value, the means are not significantly different (i.e., they are homogeneous).

Note: All calculations were rounded to two decimal places. Results may differ depending upon the number of decimal places used in each step of the calculations.

Example 2
Trichloroethylene

Influent (µg/l)	Steam stripping Effluent (µg/l)	ln(effluent)	[ln(effluent)]^2	Influent (µg/l)	Biological treatment Effluent (µg/l)	ln(effluent)	
1650.00	10.00	2.30	5.29	200.00	10.00	2.30	5.29
5200.00	10.00	2.30	5.29	224.00	10.00	2.30	5.29
5000.00	10.00	2.30	5.29	134.00	10.00	2.30	5.29
1720.00	10.00	2.30	5.29	150.00	10.00	2.30	5.29
1560.00	10.00	2.30	5.29	484.00	16.25	2.79	7.78
10300.00	10.00	2.30	5.29	163.00	10.00	2.30	5.29
210.00	10.00	2.30	5.29	182.00	10.00	2.30	
1600.00	27.00	3.30	10.89				
204.00	85.00	4.44	19.71				
160.00	10.00	2.30	5.29				
Sum: -	-	26.14	72.92	-	-	16.59	39.52
Sample Size: 10	10	10	-	7	7	7	-
Mean: 2760	19.2	2.61	-	220	10.89	2.37	
Standard Deviation: 3209.6	23.7	.71	-	120.5	2.36	.19	-
Variability Factor: -	3.70	-	-	-	1.53	-	-

ANOVA Calculations:

$$SSB = \left[\sum_{i=1}^{k} \left(\frac{T_i^2}{n_i} \right) \right] - \left[\frac{\left(\sum_{i=1}^{k} T_i \right)^2}{N} \right]$$

$$SSW = \left[\sum_{i=1}^{k} \sum_{j=1}^{n_i} x^2_{i,j} \right] - \sum_{i=1}^{k} \left(\frac{T_i^2}{n_i} \right)$$

$$MSB = SSB/(k-1)$$

$$MSW = SSW/(N-k)$$

Example 2 (Continued)

F = MSB/MSW

where:

k = number of treatment technologies

n_i = number of data points for technology i

N = number of data points for all technologies

T_i = sum of natural logtransformed data points for each technology

X_{ij} = the natural logtransformed observations (j) for treatment technology (i)

$N_1 = 10$, $N_2 = 7$, $N = 17$, $k = 2$, $T_1 = 26.14$, $T_2 = 16.59$, $T = 42.73$, $T^2 = 1825.85$, $T_1^2 = 683.30$,

$T_2^2 = 275.23$

$$SSB = \left(\frac{683.30}{10} + \frac{275.23}{7}\right) - \frac{1825.85}{17} = 0.25$$

$$SSW = (72.92 + 39.52) - \left(\frac{683.30}{10} + \frac{275.23}{7}\right) = 4.79$$

MSB = 0.25/1 = 0.25

MSW = 4.79/15 = 0.32

$$F = \frac{0.25}{0.32} = 0.78$$

ANOVA Table

Source	Degrees of freedom	SS	MS	F value
Between(B)	1	0.25	0.25	0.78
Within(W)	15	4.79	0.32	

The critical value of the F test at the 0.05 significance level is 4.54. Since the F value is less than the critical value, the means are not significantly different (i.e., they are homogeneous).

Note: All calculations were rounded to two decimal places. Results may differ depending upon the number of decimal places used in each step of the calculations.

Example 3
Chlorobenzene

Activated sludge followed by carbon adsorption				Biological treatment			
Influent (µg/l)	Effluent (µg/l)	ln(effluent)	[ln(effluent)]^2	Influent (µg/l)	Effluent (µg/l)	ln(effluent)	[ln(effluent)]^2
7200.00	80.00	4.38	19.18	9206.00	1083.00	6.99	48.86
6500.00	70.00	4.25	18.06	16646.00	709.50	6.56	43.03
6075.00	35.00	3.56	12.67	49775.00	460.00	6.13	37.58
3040.00	10.00	2.30	5.29	14731.00	142.00	4.96	24.60
				3159.00	603.00	6.40	40.96
				6756.00	153.00	5.03	25.30
				3040.00	17.00	2.83	8.01
Sum:							
-	-	14.49	55.20	-	-	38.90	228.34
Sample Size:							
4	4	4	-	7	7	7	-
Mean:							
5703	49	3.62	-	14759	452.5	5.56	-
Standard Deviation:							
1835.4	32.24	.95		16311.86	379.04	1.42	-
Variability Factor:							
-	7.00	-	-	-	15.79	-	-

ANOVA Calculations:

$$SSB = \left[\sum_{i=1}^{k} \left(\frac{T_i^2}{n_i} \right) \right] - \left[\frac{\left(\sum_{i=1}^{k} T_i \right)^2}{N} \right]$$

$$SSW = \left[\sum_{i=1}^{k} \sum_{j=1}^{n_i} x^2_{i,j} \right] - \sum_{i=1}^{k} \left(\frac{T_i^2}{n_i} \right)$$

$$MSB = SSB/(k-1)$$

$$MSW = SSW/(N-k)$$

$$F = MSB/MSW$$

Example 3 (Continued)

where,

k = number of treatment technologies

n_i = number of data points for technology i

N = number of data points for all technologies

T_i = sum of natural logtransformed data points for each technology

X_{ij} = the natural logtransformed observations (j) for treatment technology (i)

$N_1 = 4$, $N_2 = 7$, $N = 11$, $k = 2$, $T_1 = 14.49$, $T_2 = 38.90$, $T = 53.39$, $T^2 = 2850.49$, $T_1^2 = 209.96$

$T_2^2 = 1513.21$

$$SSB = \left(\frac{209.96}{4} + \frac{1513.21}{7}\right) - \frac{2850.49}{11} = 9.52$$

$$SSW = (55.20 + 228.34) - \left(\frac{209.96}{4} + \frac{1513.21}{7}\right) = 14.88$$

$MSB = 9.52/1 = 9.52$

$MSW = 14.88/9 = 1.65$

$F = 9.52/1.65 = 5.77$

ANOVA Table

Source	Degrees of freedom	SS	MS	F value
Between(B)	1	9.53	9.53	5.77
Within(W)	9	14.89	1.65	

The critical value of the F test at the 0.05 significance level is 5.12. Since the F value is larger than the critical value, the means are significantly different (i.e., they are heterogeneous). Activated sludge followed by carbon adsorption is "best" in this example because the mean of the long-term performance value, i.e., the effluent concentration, is lower.

Note: All calculations were rounded to two decimal places. Results may differ depending upon the number of decimal places used in each step of the calculations.

A.3. Variability Factor

$$VF = \frac{C_{99}}{Mean} \quad (1)$$

where:

VF = estimate of the daily maximum variability factor determined from a sample population of daily data.

C_{99} = Estimate of performance values for which 99 percent of the daily observations will be below. C_{99} is calculated using the following equation: $C_{99} = Exp(y + 2.33\ Sy)$ where y and Sy are the mean and standard deviation, respectively, of the logtransformed data.

Mean = Average of the individual performance values.

EPA is establishing this figure as a maximum because the Agency believes that on a day-to-day basis the waste should meet the applicable treatment standards. In addition, establishing this requirement makes it easier to check compliance on a single day. The 99th percentile is appropriate because it accounts for almost all process variability.

In several cases, all the results from analysis of the residuals from BDAT treatment are found at concentrations less than the detection limit. In such cases, all the actual concentration values are considered to be unknown and hence, cannot be used to estimate the variability factor of the analytical results. The following is a description of EPA's approach for calculating the variability factor for cases in which all concentrations below the detection limit.

It has been postulated that a lognormal distribution adequately describes the variation among concentrations. Agency data shows that the treatment residual concentrations are often distributed approximately

lognormally. Therefore, the lognormal model has been used routinely in EPA's development of numerous regulations in the Effluent Guidelines Program and is being used in the BDAT program. The variability factor (VF) was defined as the ratio of the 99th percentile (C_{99}) of the lognormal distribution to its arithmetic mean (Mean).

$$VF = \frac{C_{99}}{Mean} \qquad (1)$$

The relationship between the parameters of the lognormal distribution and the parameters of the normal distribution created by taking the natural logarithms of the lognormally distributed concentrations can be found in most mathematical statistics texts (see, for example, Distribution in Statistics-Volume 1 by Johnson and Kotz, 1970). The mean of the lognormal distribution can be expressed in terms of the mean (μ) and standard deviation (σ) of the normal distribution as follows:

$$C_{99} = Exp\ (\mu + 2.33\sigma) \qquad (2)$$

$$Mean = Exp\ (\mu + 0.5\sigma^2) \qquad (3)$$

By substituting (2) and (3) in (1) the variability factor can then be expressed in terms of σ as follows:

$$VF = Exp\ (2.33\ \sigma - 0.5\sigma^2) \qquad (4)$$

For residuals with concentrations that are not all below the detection limit, the 99th percentile and the mean can be estimated from the actual analytical data and, accordingly, the variability factor (VF) can be estimated using equation (1). For residuals with concentrations that are below the detection limit, the above equations can be used in

conjunction with the following assumptions to develop a variability factor.

- Assumption 1: The actual concentrations follow a lognormal distribution. The upper limit (UL) is equal to the detection limit. The lower limit (LL) is assumed to be equal to one-tenth of the detection limit. This assumption is based on the fact that data from well-designed and well-operated treatment systems generally fall within one order of magnitude.

- Assumption 2: The natural logarithms of the concentrations have a normal distribution with an upper limit equal to ln (UL) and a lower limit equal to ln (LL).

- Assumption 3: The standard deviation (σ) of the normal distribution is approximated by:

$$\sigma = [(\ln (UL) - \ln (LL)] / [(2)(2.33)] = [\ln(UL/LL)] / 4.66 \quad (5)$$

(Note that when LL = (0.1)(UL) as in Assumption 1, then σ = (ln10) / 4.66 = 0.494.)

Substitution of the σ value from equation (5) into equation (4) yields the variability factor, VF.

$$VF = 2.8$$

For concentration data with only two data points a reliable estimate of the variability of the data and hence the variability factor can not be obtained. Nevertheless, the following procedure assumes that the population of concentration data from which these two samples were drawn is lognormally distributed. It is also assumed that the values of these two samples represent an estimate of the range (min and max) of population data.

The standard deviation σ of the corresponding normal distribution can be estimated using the ratio of the two available data points, R, (larger value/smaller value) as

$$\sigma = [\log (R)]/(2*2.33) = \log R/4.66 \qquad (6)$$

For several values of R (10,20,...100), the value of VF was obtained and tabulated in Table A-2. To use Table A-2 to find the VF (as calculated using equaltion (4)), the ratio of the larger value to the smaller value is obtained and rounded to the nearest R value in the Table. Alternatively, VF can be calculated by combining equations (4) and (6). The treatment standard is then calculated as

$$C_{99} = (VF)\ (mean) \qquad (7)$$

The mean is the average of the two treatment values.

Table A-2
Variability Factors When Only Two Data Points Are Available

Ratio of larger value to smaller value (order of magnitude)	Variability Factor
5	2.11
10	2.80
20	3.64
30	4.20
40	4.62
50	4.97
60	5.27
70	5.52
80	5.75
90	5.95
100	6.14